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AIR POLLUTION AND HEALTH: GENERAL DESCRIPTION OF A STUDY IN NASHVILLE, TENNESSEE

Louis D. Zeidberg, et al

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

1960

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NASHVILLE, TENNESSEE

AIR POLLUTION
PROGRAM

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AIR POLLUTION AND HEALTH: GENERAL DESCRIPTION OF A STUDY IN NASHVILLE, TENNESSEE

ABSTRACT

The Public Health Service Air Pollution Medical and Air Pollution Engineering Programs have conducted a joint study of air pollution in Nashville, Tennessee, with the School of Medicine of Vanderbilt University. Objectives of the study were to investigate possible relationships between air pollution and the health of people and to obtain information on a number of aspects of the engineering and meteorological aspects of air pollution.

The four phases of the medical study are described. They include a morbidity survey, a mortality survey, a clinical study of individuals with known chronic cardio-respiratory disease, and an anthracosis study of autopsied individuals.

The extensive aerometric studies are described in terms of objectives and equipment and methods used. General descriptive information concerning the study area is presented.

I

AIR POLLUTION AND HEALTH: GENERAL DESCRIPTION OF A STUDY IN NASHVILLE, TENNESSEE

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"Take of London fog 30 parts; malaria 10 parts; gas leaks 20 parts; dew drops gathered in a brickyard at sunrise 25 parts; odor of honeysuckle 10 parts. Mix. The mixture will give you an approximate composition of a Nashville drizzle."

------ A Municipal Report, O. Henry ------

The acute health effects of air pollution have been observed in several, short-term acute episodes that occurred in the Meuse Valley, Belgium, Donora, Pennsylvania and London, England.[1] More difficult to assess but of possibly equal importance, are the chronic or long-term effects that may occur as the result of daily, and often lifetime, exposure to sub-lethal levels of contaminants in an urban atmosphere. Mortality studies in this country[2,3] and mortality and morbidity studies elsewhere,[4,5,6] have demonstrated the likelihood of such effects and the need for further evaluation.

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The City of Nashville, Tennessee, was selected for studies designed primarily to develop study methods in the field. The selection of Nashville was based on the belief that it is a community with a chronic, but relatively modest air pollution problem; that the pollution in large measure is caused by a single agent, coal smoke.

CONDUCT OF THE STUDY

The two organizations of the Public Health Service engaged in the field of air pollution research, the Medical Program and the Engineering Program, conducted a joint study. Cooperating were the Tennessee Department of Public Health, the Davidson County Health Department, the Office of the Mayor of Nashville, the Nashville Division of Smoke Regulation, and many other governmental and private agencies and individuals.

Work on the health phase of the study was done largely by the Department of Preventive Medicine and Public Health, School of Medicine, Vanderbilt University, under terms of a contract with the Public Health Service, [7] with some direct operational work being done by Public Health Service staff. A morbidity survey was conducted by the Survey Operations Unit of the University of North Carolina and the North Carolina State University. [8]

Work on the engineering phase of the study was done by Public Health Service staff assigned in Nashville and operating out of the Robert A. Taft Sanitary Engineering Center in Cincinnati. Meteorological studies were conducted by U.S. Weather Bureau staff assigned to Air Pollution Engineering Research at the Sanitary Engineering Center with field operational work being done largely by Public Health Service staff stationed in Nashville. A laboratory and office were established for the engineering phase of the work in quarters leased from the Tennessee Department of Public Health, but some chemical analytical work was done at the Sanitary Engineering Center. Machine data computations were done in part by the State of Tennessee, Department of the Budget, Data Processing Division. Other data processing was done by the Public Health Service in Cincinnati.

Design work of the medical phase of the study began in the fall of 1957, with operational work starting in the spring of 1958. The major morbidity survey was conducted during the first three months of 1959, while various phases of investigative work were completed from time to time during 1958 and 1959. The over-all project was completed in July of 1959.

Design work of the engineering and physical sciences phase of the study began in late 1957. Establishment of aerometric stations and the laboratory was completed by August 1958, while field work was done on a continuous basis from August 1958 through July 1959.

GENERAL DESCRIPTION OF THE NASHVILLE AREA

Topography

Nashville is located in Davidson County, in the north-central part of Tennessee, on the Cumberland River. Topographically the city is situated in a basin with hills to the south, west and north, forming an amphitheater around the city. The hills rise generally to a height of 300 to 400 feet above the mean elevation of the basin, with some higher peaks. The country to the northeast, east, and southeast is more or less open with undulating hills. 9/

Climate

Nashville has a moderate climate with a normal monthly average temperature of 80 degrees F. in July, the warmest month, and 40 degrees F. in January, the coldest month. Normally there are about 3500 heating degree days per year. Precipitation is ample and fairly evenly distributed throughout the year, while the average annual snow-and sleet-fall of about eight inches is seldom sufficient to interfere with outdoor occupations more than a few days in a season. The area has a moderate frequency of thunderstorms. Prevailing winds are from the south in all months except September when north winds prevail. Monthly average wind speed ranges from 6.6 mph in August to 10.4 in March. 9/

The People of Nashville

The City of Nashville, in 1958, had a population of about 167,000. The metropolitan area of Nashville (all of Davidson County) had a population of about 375,000. About one-third of the city residents of Nashville are Negro, and there are few foreign-born. The white population had no unusual mortality experience except for a slightly increased death rate due to parasitic and infectious diseases of the gastro-intestinal tract, to homicide, and to senility and other ill-defined causes.[10]

Dispersion of Pollution

During most of the year, meteorological conditions are generally favorable for dispersion of pollutants. However, there are occasions, especially during the fall and early winter, when the atmosphere is unable to disperse airborne materials adequately, and pollutants tend to accumulate over the city. There are many mornings and evenings when a pall of pollutants can be seen.[11] Visual observations indicate that considerable variations in pollution levels occur within the Nashville area. Data presented by Korshover[12] indicate that Nashville is located in an area in which the weather is relatively often dominated by stagnating anticyclones which persist for four days or more. Such conditions lead to accumulation of pollutants. In Nashville, stagnating anticyclones occur most frequently in October.

Air Pollution in Nashville [11]

Nashville has had a long history of major smoke problems. A report dated 1935 stated[13] "Few cities in the United States have a greater smoke nuisance to contend with during the winter months than Nashville. It has been so dense on occasions that the visibility was reduced to zero, the sun's disc invisible from street level, and street and automobile lights kept burning until after 10 a.m., although at the same time just outside the smoke area the sky was brilliantly clear." The smoke problem is not as severe now as it was years ago, but smoke and other air pollutants still are a matter of considerable concern. Limited air sampling done in 1957 indicated that pollution due to suspended particulate matter was about equal to that in other cities of comparable size.[14]

Sources of pollution include space and water heating plants, industrial plants, transportation equipment, and refuse burners. Energy for domestic space and water heating is currently derived about 35 percent from bituminous coal, 40 percent from natural gas, 15 percent from electricity, and some oil and wood. A considerable amount of coal is used by commercial and industrial plants, along with natural gas and oil. Natural gas usage by domestic consumers increased almost fourfold from 1948 to 1958. Commercial and industrial use of natural gas increased almost eightfold in the same period, indicating a substantial change of fuel from coal to gas by these two types of consumers, as well as expanding human activity. Rubbish burning on domestic premises is a widespread practice. Refuse is also disposed of in sanitary landfills. Leading industries include printing, chemicals, food products, fabricated metals, and leather. Individual industrial plant emissions which have been recognized as problems in Davidson County include smoke from fire-cleaning of scrap automobiles, dust from crushed limestone, cement, and brick works; acid, dust, ammonia, and fluorides from fertilizer and phosphate plants; foundry dust and fumes; acids and lead from battery plants; acids and alkalies from electroplating; carbon disulfide and hydrogen sulfide from a rayon plant, and various others. 11/ Transportation equipment includes some 132,000 motor vehicles (Davidson County, 1956) which consume about 300,000 gallons of gasoline per day; locomotives (all diesel) operating on three railroad lines; buses; trucks; and some river vessels. All of these emit pollutants to the atmosphere. 11/

MEDICAL PHASE OF THE STUDY

Four separate but related medical studies were conducted: (1) a morbidity survey, (2) a mortality survey, (3) a cardio-respiratory disease study, and (4) an anthracosis study.

The Morbidity Survey

Objectives

1. To obtain general and specific morbidity data of residents of the City of Nashville and its suburban fringe.

2. To determine whether there is an association between any morbid conditions and exposure to air pollutants.

Plan of the Study

A questionnaire was prepared and pretested in the field in a distant part of the county that was not to be included in the final survey. The questionnaire was designed to provide general as well as specific information concerning the occurrence of morbid conditions and disability on the day of the interview, during the previous two weeks, the previous year, and in the past. In most cases, the respondent was the wife of the head of the family who furnished information for all other members of her family. A probability sample of approximately five percent of the occupied dwellings in the study area was selected. Interviewing began in January 1959, and was concluded in March.

In order to provide a check on validity of information obtained during the interview, 106 families comprising 377 individuals were examined by a physician within a short time after the interview. Examinations were done by experienced internists and pediatricians in special night clinics organized for the purpose at Vanderbilt University Hospital. Complete histories were taken and physical examinations performed on each individual. In addition, the following screening procedures were done: complete blood, urinalysis, chest film, EKG, Wasserman, and pulmonary function tests. Papanicolaou smears were done on married females.

Other verification of illness and disability reported on interview was obtained by securing information from medical records of doctors and hospitals for reported attended-illness of a ten percent sample of the survey group.

Analysis of Data

Data will be analyzed to show differences in occurrence of specific morbid conditions in different areas of the city, by such variables as age, sex, race, and socio-economic status. Air quality data will be used to determine whether an association can be shown between degree of atmospheric pollution and the frequency of any morbid conditions.

The Mortality Survey

Objectives

1. To determine mortality rates for specific causes by census tracts for residents of the Standard Metropolitan Area of Nashville.

2. To study the relation between these death rates and demographic, social, and economic data for these census tracts.

3. To determine whether deaths for specific causes vary significantly with residence in areas of relatively high or low atmospheric pollution.

Plan of the Study

Approximately 25,000 deaths were reported in Davidson County including Nashville from 1949 to 1956. This span of years was selected because it is the period of time between revisions of the Manual of the International Statistical Classification of Disease, Injuries, and Causes of Death. Data obtained from death certificates included age, sex, race, marital status, residence at time of death, occupation and industry, and immediate, contributory, and underlying causes of death. For purposes of this study it was necessary to allocate the residence at time of death to a specific census tract and planning unit. Accordingly a coding guide was prepared which listed by number the census tract and planning unit for every official street in the county except for non-tracted areas.

Since the only population data available from the Bureau of the Census dated back to 1950, it was necessary to estimate the total population for the study period. Data from the 1950 census,[15] Nashville-Davidson County Advance Planning Commission estimates for 1958 [16] in conjunction with data from the morbidity survey, and the mortality statistics themselves, were used to estimate the base.

Analysis of Data

Specific causes of death by age, sex, and race will be determined for each census tract. The census tracts will be grouped into five socio-economic classes based on median rental from data obtained during the morbidity survey and the 1950 census. Mortality rates for specific causes will be analysed in relation to air quality data.

Cardio-Respiratory Disease Study

Objectives

1. To determine whether individuals known to have a specific cardio-respiratory disease show variation in frequency or severity of their attacks depending on diurnal or seasonal variation in their exposure to environmental air pollutants.

2. To determine whether the course of disease in individuals known to have a specific cardio-respiratory disease differs according to their residence in areas of relatively high or low air pollution.

Plan of the Study

One hundred twenty-three patients, children and adults, were selected from the Vanderbilt University Hospital Out-Patient Department clientele and from among private patients of local physicians. Included in the study were 49 adults and 35 children with bronchial asthma, and 39 adults with other cardio-respiratory diseases. All patients were given a complete physical examination after a detailed history was obtained. All were given periodic pulmonary function tests. The asthmatics were asked to mail a weekly report card (Fig. 1) with information concerning number of attacks each day, time of onset, duration, place of occurrence, and medication used. The other patients on the panel were asked to mail a different report card (Fig. 2) indicating their status each day as either the "same", "better", "worse", or "much worse" than usual.

Pollen counts were made seasonally to provide data needed for control of an important variable in the occurrence of asthmatic attacks.

Analysis of Data

The frequency of asthmatic attacks and the daily status change of the non-asthmatic panel patients will be compared with meteorological variations and changes in concentration of air pollutants. The residence of each patient with respect to local environmental air pollution will be studied in relation to the course of disease.

Anthracosis Study

Objectives

1. To determine whether residents of Nashville examined at autopsy have a greater degree of anthracosis than non-residents.

2. To determine whether the degree of anthracosis in Nashville residents varies according to the area of their residence in the city.

3. To determine whether anthracosis in Nashville residents is related to length of their residence in the city.

4. To determine whether anthracosis is commonly associated with any other pulmonary or any cardiac pathology.

5. To determine whether anthracosis is identified with any specific symptomatology.

Plan of the Study

Data were obtained on 641 autopsies done at Vanderbilt University Hospital between 1953 and 1956 inclusive. Consecutive autopsies were studied with the exception of individuals under five years of age and a relatively small number of cases in which there were either no lung sections available for study or for which there were insufficient clinical data. This study was a completely "blind"

investigation in which various categories of data were independently obtained in order to guard against introduction of bias. The degree of anthracosis was evaluated with the help of standards prepared by Dr. John L. Shapiro, Professor of Pathology of Vanderbilt University School of Medicine. The chief anatomical cause of death, and other cardio-respiratory pathology found at autopsy were obtained directly from the official autopsy protocols of Vanderbilt University Hospital. Cardio-respiratory disease symptoms that were present during terminal illness and at any previous time were obtained from the history recorded in the Vanderbilt University Hospital charts. Residence data and occupational data for as many as 20 years before death were obtained for Nashville residents from city directories. All others were grouped as out-of-city residents and no further effort was made to obtain residence or occupational data.

Analysis of Data

Variations in degree of anthracosis will be determined in the autopsy group according to age, sex, race, and residence factors. Comparisons will be made of the degree of anthracosis with frequency of cardio-respiratory symptoms and with occurrence of cardio-respiratory pathology. Among residents of Nashville a comparison will also be made of the degree of anthracosis and residence in an area of high or low air pollution.

Engineering and Physical Sciences Phase of the Study

Objectives

Provisions were made for operational testing of various field study design factors and means of conducting air pollution field studies. These objectives were interwoven with the mission of providing air quality data for use in medical studies. Objectives were as follows:

1. Determine representativeness of air quality data with respect to number and location of sampling stations, sampling frequency, and sampling time, all as related to various uses of the data.

2. Make operational evaluations of the study design employed; of analytical methods for determining pollutants; and of equipment and procedures used.

3. Study dispersion of air pollutants arising in an urban area as related to source distribution and meteorological parameters and evaluate methodologies for such studies.

4. Determine public opinion regarding air pollution as related to pollution levels and population characteristics.

5. Determine the extent to which radiosonde data from the U.S. Weather Bureau airport station can be used to classify stability of the lower atmosphere over the urban area into broad classes of "stable" and "unstable".

6. Determine relationships between air pollution concentrations at a selected station and meteorological parameters measured at the same station, and at different stations.

Aerometric Station Network

Aerometric stations were established at 123 sites in the Nashville area. Of these, 119 were located at the intersection of lines forming an equilateral triangle grid pattern in the urbanized part of the area. These stations covered an area about nine miles in diameter, centered around Ninth and McGavock Streets in downtown Nashville (station 60). Control stations were located in the four cardinal compass directions from the central station and about three miles beyond the station network (Figure 3). Stations were placed about 0.87 miles apart. The triangular grid was selected in preference to other patterns in order to reduce the number of stations needed to provide a sampling site within one-half mile or less of all points in the area. This distance was selected on the basis of some experience with studies of relationships between air pollution and health conducted in England, but must be considered as a rather arbitrary judgement based on limited factual data.

The precise placement of aerometric stations was dependent upon availability of access streets, electric power (at two types of stations), and freedom from obstructions to air movement required for use of certain equipment. At stations equipped with wind measuring instruments it was necessary to give consideration to topographical features near these stations and to have a utility pole upon which to mount wind sensing elements. In some cases these various requirements made it necessary to locate stations some distance away from the corners of grid triangles, and in a few cases to deviate from uniform spacing.

The aerometric network consisted of three general types of station with one (type III) being further divided into four sub-types. There were several additional stations for specific measurements. The urbanized area was covered in a reasonably uniform manner with respect to all three types of station (Figure 3). Measurements at type I stations were simple, consisting of dustfall collection and indication of sulfur dioxide by the lead peroxide candle method. Type II stations were provided with the same equipment as Type I stations, and in addition were equipped to obtain a volumetric measure of sulfur dioxide and soiling by suspended particulate matter (one 24-hour filter paper sampler per day for each). Type II stations were equipped with a wind odometer to provide a measure of total air movement for each 24-hour period. Type III stations were equipped with all the same apparatus as Type I and Type II stations, and in addition, other apparatus. A description of all activities conducted on a routine basis is summarized in table 1.

At Type I stations equipment was mounted on a cross arm attached to a utility pole at about eleven feet above ground (Figure 4). At Type II stations, equipment was mounted on a cross arm attached to a utility pole, with some of the equipment housed in a ventilated cabinet, also at about eleven feet above ground. The sensing element for a wind odometer was mounted top of the pole with the counter located in the cabinet (Fig . 5, 6). At Type III stations, lead peroxide candle an ustfall equipment was mounted in the same manner as at Type I and II stations. Other equipment was housed in a walk-in shelter (Figure 7). Sensing elements for wind measuring equipment were mounted on top of the utility pole, with registering instruments housed in the shelter.

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Methods for Routine Aerometric Measurements

Dustfall

Settled dust was collected by use of plastic waste-paper containers. They were 10-3/4 inches high, 7-3/4 inches in diameter at the top, and 6-3/8 inches at the bottom. Water was placed in each collector on setting it out. Material from all collectors was analyzed for total water insolubles. Samples from the eleven Type III stations were given additional analysis. Water soluble matter was determined and the water insoluble matter was further analyzed for benzene solubles, for combustibles other than those soluble in benzene, and for ash.

Sulphur Dioxide by the Lead Peroxide Candle Method

Sulphur dioxide was determined by the lead peroxide candle method at all sampling stations. Methods and equipment used[17] were similar to those described by Parker and Richards[18] with modifications developed by the Tennessee Valley Authority. Candles were exposed for about 30 days. Results may be used to obtain an estimate of mean atmospheric concentration of sulfur dioxide in parts per million.[19]

Soiling (Suspended Particulate Matter)

At all Type II and III stations, 24-hour samples were collected daily for determination of soiling power of suspended particulate matter (and sulfur dioxide). The sampling train consisted (in order) of a glass sampling probe, strip filter paper holder, large bubbler, glass wool trap, limiting (critical) orifices, and a pump. The system was arranged to provide a constant flow of 0.5 liters per minute through the bubbler (used for sulfur dioxide measurement) and 0.5 to 1.5 liters per minute through the filter paper, the rate depending on air volume needed to obtain a sample of suitable optical density. The filters were short pieces of strip filter paper usually used in AISI type samplers (Whatman No. 4). Evaluation of the amount of suspended particulate matter collected was done by measuring light transmission through the sample spot and through clean filter paper adjacent to the sample spot and noting the difference. A spot evaluator usually used for AISI strip filters was employed.[20]

At all Type III stations, soiling power of suspended particulate matter was determined also on a two-hourly basis in high pollution seasons and on a four-hourly basis in low pollution seasons. AISI type strip filter paper samplers were used with Whatman No. 4 filter paper. [21, 22] Sample spots were evaluated by measuring light transmission through the sample spot and a clean place on the filter, and noting the difference. A manual spot evaluator [20] and an automatic spot evaluator with a digital recorder [23] were used. A sampler calibration technique and method of computation was used which minimized possible errors in results. [24]

Volumetric Sulfur Dioxide Determination

Three different classes of volumetric sulfur dioxide determination were made. These were 24-hourly and two-hourly samples collected and analyzed by a method adapted from a procedure described by West and Gaeke [25] and a Thomas Autometer. [26, 27] At all Type II and III stations, 24-hourly samples were collected in large fritted bubblers. The bubblers were part of the 24-hourly sampling train described above. At Type III stations (Type III C excepted) twelve two-hourly samples were also collected each day, using midget fritted bubblers with automatic sequential samplers. [28] Analytical procedures followed recommendations of West and Gaeke except that a 0.005 percent rosaniline hydrocholoride - 5 percent hydrochloric acid mixture was used instead of 0.04 percent - 6 percent. The modification was necessary [17] to overcome difficulties encountered in use of the automatic analytical device [29] employed in analysis of all bubbler-collected samples of sulfur dioxide. The Thomas Autometer was operated continuously at the Type III X (central) station.

Suspended Particulate Matter

High volume filter paper samplers [30] were operated at all Type III stations, collecting one 24-hour sample per day, using 8 by 10 inch sheets of flash-fired glass fiber filter web. [31] Samplers were placed with the filter horizontal at the lower end of a vertical duct which extended through the roof of walk-in shelters.

Total weight of particulate matter collected was determined gravimetrically. In addition, the two samples indicating the highest concentration of particulate matter in air, and the one sample indicating the lowest concentration for each calendar month at each of 11 stations (total of 33 samples per month) were analyzed for total organic matter, nitrates, and sulfates. Analytical procedures were those employed in the Public Health Service National Air Sampling Network. 14/

High volume filters from urban stations (all Type III stations except III C) not used for the foregoing analyses were extracted with benzene to obtain organic matter from them. Part of the total organic extracts were sent to the National Cancer Institute for animal studies of possible carcinogenicity. The rest of the organic extracts were separated into three classes of compounds: (1) aromatic hydrocarbons; (2) aliphatic hydrocarbons; (3) oxy-neutral compounds. The latter two fractions were used at the University of Southern California by Dr. Paul Kotin for animal studies of possible carcinogenicity. The aromatic hydrocarbons were sent to the National Cancer Institute for similar use.

Suspended particulate matter was also collected at station III X from September 1958 through July 1959 using membrane filters. 32/ Each filter was used for four weeks unless particulate matter collected caused excessive pressure drop across the filter. In such cases, a shorter time (two to four weeks) was used. Filters were sent to the National Cancer Institute where particulate matter was removed mechanically and used for animal studies of possible carcinogenicity. This technique made particulate matter available which had not been altered by chemical extraction or separation nor contaminated with filter media.

Nitrogen Dioxide, Oxidant, and Carbon Monoxide

Nitrogen dioxide and oxidant concentrations in the atmosphere were measured continuously at station III X (central station) using an automatic recording instrument. 33/ The three channel instrument is designed for measurement of nitric oxide also, but this part of the instrument was not used. Determination of nitrogen dioxide is based on a

method described by Saltzman. [34] Oxidant determination by the instrument makes use of the neutral potassium iodide method and is based on a design by Littman and Benoliel. [35]

Atmospheric carbon monoxide was continuously measured and recorded at station III X using a Luft type non-dispersive, selective, infrared analyzer. [36]

Photographs Depicting Visibility and Visual Range Observations

Photographs were taken routinely to provide a record of the appearance of the air over Nashville and to develop a relationship between appearance of the air mass and pollution levels. Photographs were taken in three directions (north, east, and west) from the roof of the Cordell Hull Building (about 130 feet above ground) at 0900 and 1500 CST each day. Visual observations were made of sky conditions (cloudy, clear, etc.) at the time pictures were taken.

Observations of visual range were also made from the roof of the Cordell Hull Building at 0900 and 1500 CST each day. Visual range was recorded as the number of miles from the point of observation to the farthest away of certain landmarks which could be seen by the observer. The technique was patterned after that used by the U.S. Weather Bureau. [37]

Wind Measurements (Surface)

Total wind movement for each 24-hour period was measured at all Type II and III stations using wind odometers. [38] A three-cup anemometer was mounted on top of utility poles at about 33 feet above ground.

Wind direction and velocity recording units [39] were operated at Type III M stations. Three-cup anemometers with wind vanes were mounted on top of utility poles along with wind odometers at about 33 feet above ground.

Wind speed and direction data from the U.S. Weather Bureau Station at Nashville Municipal Airport (Berry Field) were obtained. Instruments in use are standard U.S.

Weather Bureau type and sensing elements are mounted at about 43 feet above ground.

Wind Speed and Direction (Upper Air)

Two wind speed and direction transmitters were installed on the WSM-TV tower at about 251 and 501 feet above ground, with continuous dual recorders at ground level. [40] Transmitters were mounted on arms extending out about four feet from a corner of the tower.

Four upper air wind observations are made daily by the U.S. Weather Bureau Station at Berry Field. These are made at 0600 and 1800 CST using standard Weather Bureau rawinsonde equipment, and at 1200 and 2400 CST using pilot balloons (pibals). Wind speed and direction are determined at specified levels from the surface to the elevation of the balloon at termination of the flight.

Temperature, Relative Humidity, and Barometric Pressure

Temperature and relative humidity were continuously recorded at Type III M stations using recording hygrothermographs. [41] Instruments were housed in standard U.S. Weather Bureau, Cotton Belt Region, thermometer shelters. Wet-and dry-bulb temperatures were measured each hour by the U.S. Weather Bureau station at Berry Field.

The U.S. Weather Bureau station at Berry Field makes measurements of temperature, relative humidity, and barometric pressure in the upper air using radiosondes. Balloons are released at 0600 and 1800 CST each day. Standard Weather Bureau equipment and procedures are used. Data are obtained from the surface to the elevation of the balloon at termination of the flight.

Solar, Sky, and Terrestrial Radiation

A recording actinometer (pyrheliograph) [42] was operated continuously on the roof of the Cordell Hull Building. (Figure 3). The instrument provides a measure of intensity of direct solar and sky radiation. The duration of sunshine was measured continuously at the U.S. Weather Bureau station at Berry Field using a Marvin sunshine recorder. [43]

From December 1958 to June 1959, continuous measurements were made of incoming solar and sky radiation and outgoing terrestrial radiation, the difference being net radiation. A recording economical net radiometer of the type described by Suomi [44, 45] was used.

Other Meteorological Measurements

Other meteorological measurements not described previously are those ordinarily made at U.S. Weather Bureau first order stations. [9] These are made routinely by the Bureau's station at Nashville Municipal Airport (Berry Field).

Special Non-Routine Studies

Sulfur Dioxide Emission Inventory

Contemplated studies of dispersion of pollutants in the atmosphere and other studies made it necessary to obtain a knowledge of sources of at least one pollutant. Sulfur dioxide was selected as most useful in this work because of the broad distribution of sources, the availability of data concerning characteristics of its sources, and because it was to be measured at a large number of stations.

The emission inventory was prepared on the basis of emission rates given in the literature; tabulations of the size, nature, and location of sources; fuel use data; engineering estimates of emissions from sizeable industrial sources; meteorological data (especially degree day values); questionnaires completed by industrial plants; and data concerning domestic fuel use obtained as a part of the morbidity survey. Data were tabulated for one mile square areas. Data for determining diurnal and seasonal variations were obtained. Height above ground of points of emission were obtained individually for major sources and estimates of average height of emission were made for multiple type sources such as chimneys of dwellings. The work was supervised by Dr. H. J. Paulus of the University of Minnesota.

Study of Dustfall Measurement Techniques

A study was made of several types of dustfall collector for the purpose of evaluating variation in amount of dustfall

collected by different types, variation in collection between a number of the same type collector at a given location, and desirability of collectors from the standpoint of ease of use. Further verification of previous work [46] was sought. Types of collectors used included simple polyethylene waste baskets with and without added liquid; polyethylene waste baskets with baffles, with and without added liquid; simple polyethylene collectors with thin, removable plastic liners; and a tall, slim cylindrical collector used in Canada.

Public Opinion of Air Pollution

An effort was made to determine public awareness of air pollution; opinion of what level of pollution is "too high"; what aspects of pollution people are concerned about and interested in; and what importance the public attaches to air pollution in relation to other problems confronting them. Opinions expressed by about 3000 people will be examined in the light of pollution levels and pollution sources influencing individuals and their socio-economic status. These data were obtained as part of the morbidity survey.

Pollen Measurements

Atmospheric pollen concentrations were determined by use of flag samplers [47] operated at 10 stations in the aerometric network, from September through November 1958 and from March through June 1959. During the earlier time period volumetric samples of pollen were collected at station 60 and during the later time period at station 48 by drawing air through a membrane filter. Pollens were counted and identified at the University of Michigan under the direction of Dr. E. W. Hewson, under contract.

Pollution Level Forecasts

In order to test the possibility of predicting the pollution situation by meteorological methods, daily forecasts of pollution levels for the following day were made. Factors considered were wind speed and the difference between temperature at the surface and at the 900-millibar level, an index of stability. Forecasts indicated whether high, moderate, or low pollution levels were expected. The U.S. Weather Bureau station at Berry Field did this work during the period January 23 through July, 1959.

Automobile Traffic Counts

A continuous count was made of automobiles passing in the street along-side station 60 for a period of four months. Recorded counts will be used in interpretation of results of continuous measurements of carbon monoxide at the same location.

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SUMMARY

The multiple objectives of this study were considered to be sub-objectives of two primary problems:

1. How to assess the atmospheric pollution of a community most accurately, with reference to both temporal variations and long-term averages, in relation to quantity, composition and the factors affecting it, and;

2. How to assess the health effects that might result from this contamination as they varied in geographic and temporal distribution, recognizing that many other factors also might affect them.

These problems arose as the result of a relatively simple assumption: That health effects might vary consequent to exposure, both in time and geographically.

A very large study was therefore undertaken, primarily to ascertain whether proper measurements and experimental procedures could be designed to meet these objectives.

The present report describes the overall study. Analysis of data is proceeding and as results of these analyses are obtained, they will be made generally available.

Note: Any mention of specific commercial products does not imply in any way endorsement of these products or recommendation of them over similar commercial products. Commercial names are given to reduce the need for descriptive material herein and to improve understanding of the work described.

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TABLE 1

SUMMARY OF BOUTINE AEROMETRIC PROGRAM
NASHVILLE AIR POLLUTION STUDY

STATION	NUMBER OF STATIONS	MEASUREMENTS MADE	EQUIPMENT	FREQUENCY OF MEASUREMENT	ANALYSES MADE	ANALYTICAL METHOD	REMARKS
Type I	07	Dustfall	Plastic dustfall collectors - wet bottom	1 - 30 day sample per month	Weight of water insoluble matter	Filter contents of collector, dry, and weigh	Sampling equipment mounted on utility poles
		Sulfur dioxide	Lead peroxide candle	1 - 30 day sample per month	Sulfur trioxide determined as sulfate	Barium chloride method for sulphate; gravimetric	
Type II	05	MEASUREMENTS MADE AT TYPE I STATIONS ALSO MADE AT ALL TYPE II STATIONS					
		Soiling (Suspended particulate)	Sampling train of filter paper, bubbler, trap, orifice, and pump	1 - 24 hour sample per day	Change in light transmission through filter paper	Photometric	Sampling equipment mounted on utility poles
		Sulfur dioxide		1 - 24 hour sample per day	Sulfur dioxide	West and Gaeke method	Laboratory analyses made using Technicon Autoanalyzer
		Total wind movement	Airways Weather Bureau fb02 Odometer	1 - 24 hour total per day	Total wind movement per 24 hour period	Automatic counter read daily	Sensing elements about 33 feet above ground
Type III	2	MEASUREMENTS MADE AT TYPE I AND TYPE II STATIONS ALSO MADE AT ALL TYPE III STATIONS					Dustfall also analyzed for water soluble; benzene soluble; other combustible; ash
		Suspended particulate	High volume filter paper sampler	1 - 24 hour sample per day	All samples - total weight of particulate matter	Gravimetric	Benzene extracts of many samples fractionated and used for animal studies of possible carcinogenicity
					One sample in ten - Further analyses made for total organics; nitrate; and sulfate	As used in U.S. Public Health Service National Air Sampling Network	
		Soiling (Suspended particulate)	AISI strip filter paper sampler	12 - 2 hour or 6 - 4 hour samples per day	Change in light transmission through filter paper	Photometric	2 hour samples in high pollution seasons; 4 hour samples in low pollution seasons
		Sulfur dioxide	Automatic sequential sampler with midget bubblers	12 - 2 hour samples per day	Sulfur dioxide	West and Gaeke method	Atmospheric air filtered before passing through bubbler. Laboratory analyses made using Technicon Autoanalyzer
Type III N	4	MEASUREMENTS MADE AT TYPE III STATIONS ALSO MADE AT ALL TYPE III N STATIONS					
		Wind speed; wind direction	Beckman and Whitley Model K 100 wind system	Continuous strip chart record	Wind speed - average; maximum; and minimum hourly Wind direction - average; highest veering and backing direction - all hourly	Strip chart observation and data reduction	Sensing elements about 33 feet above ground. Fifth highest veering and backing direction used August 1958 through January 1959
		Temperature; relative humidity	Friez Hygrothermograph Model 594	Continuous strip chart record	Average hourly values taken from charts	Strip chart observation and data reduction	Instrument in Weather Bureau Cotton Region type shelter
Type III C	4	MEASUREMENTS MADE AT TYPE III STATIONS WERE MADE AT ALL TYPE III C STATIONS EXCEPT THAT TWO-HOURLY SULFUR DIOXIDE MEASUREMENTS WERE NOT MADE					
Type III X (Central Station;	1	MEASUREMENTS MADE AT TYPE III STATIONS MADE ALSO AT THE TYPE III X STATION					
		Sulfur dioxide	Thomas Autometer	Continuous strip chart record	Sulfur dioxide	Change in electrolytic conductivity of hydrogen peroxide - sulfuric acid absorbing solution	
		Nitrogen dioxide	Kruger Model 73 Atmosphere Analyzer	Continuous strip chart record	Nitrogen dioxide	Automatically recorded colorimetric analysis based on method described by Saltzman	Nitric oxide channel of recorder not operated successfully
		Oxidant			Oxidant	Automatically recorded colorimetric analysis based on neutral KI reaction	
		Carbon monoxide	N.S.A. Luft type non-dispersive infrared analyzer	Continuous strip chart record	Carbon monoxide	Absorption of infrared radiation converted to electrical output signal	
		Suspended particulate matter collected	Positive displacement pump; sheets of membrane filter media	Sampler run continuously. Each filter used 2 - 4 weeks	Particulate matter mechanically removed for use as collected		Collected material used for animal studies of possible carcinogenicity
Cordell Hull Building	1	Visual range	Human observer	0900 and 1500 CST daily		Visibility of certain objects at known distances away was noted	
		Photographs	Camera	0900 and 1500 CST Daily		Appraisal of degree of haze as shown on pictures	Picture taken in three compass directions
		Incoming radiation	Instrument Corp. Actinometer	Continuous strip chart record	Average hourly total incoming radiation	Instrument operates on a differential heating principle	
Television Tower	1	Upper air wind speed; wind direction	Bendix-Friez Aerovane	Continuous strip chart record	Same as at Type III N stations	Same as at Type III N stations	Sensing units at 251.5 and 501.5 feet above ground - recorder at ground level
Downtown park area	1	Net radiation	Suomi Economical Net Radiometer	Four times per minute-recorded	Net radiation. (Difference between incoming solar and sky radiation and outgoing terrestrial radiation)	Output of thermopiles recorded	Located in small park area near downtown area near Cordell-Hull Building
U.S. Weather Bureau Airport Station Berry Field	1	Upper air winds	Pilot balloons and rawinsonde	4 per day at 0600; 1200; 1800; and 2400 CST	Wind speed and direction at specified levels		Pilot balloons at 1200 and 2400 CST Rawinsonde at 0600 and 1800 CST
		Sunshine	Marvin Sunshine Recorder	Continuous strip chart record	Minutes of sunshine each hour	Instrument is a differential air thermometer	
		Upper air temperature; pressure; relative humidity	Radiosonde units	0600 and 1800 CST daily	Temperature, relative humidity, and pressure in upper air		Other measurements usually made at USWB first order stations are available

IND. NO._____	ASTHMA CALENDAR				REPORT NO._____		
DATE	MON. _____	TUES. _____	WED. _____	THUR. _____	FRI. _____	SAT. _____	SUN. _____
TIME ATTACK STARTED							
TIME ATTACK ENDED							
MEDICINE TAKEN	YES NO	YES NO	YES NO	YES NO	YES NO	YES NO	YES NO
PLACE OF ATTACK							
NO ATTACK							

C-R Form 2

FIGURE 1 - Weekly Report Card Used by Asthmatic Patients in Cardio-Respiratory Disease Study

IND. NO._____	C-R CALENDAR				REPORT NO._____		
DATE	MON. _____	TUES. _____	WED. _____	THUR. _____	FRI. _____	SAT. _____	SUN. _____
BETTER							
SAME							
WORSE							
MUCH WORSE							

C-R Form 4

FIGURE 2 - Weekly Report Card Used by Patients (Other Than Asthmatics) in Cardio-Respiratory Disease Study

FIGURE 3 - Aerometric Station Network for Nashville Community Air Pollution Study

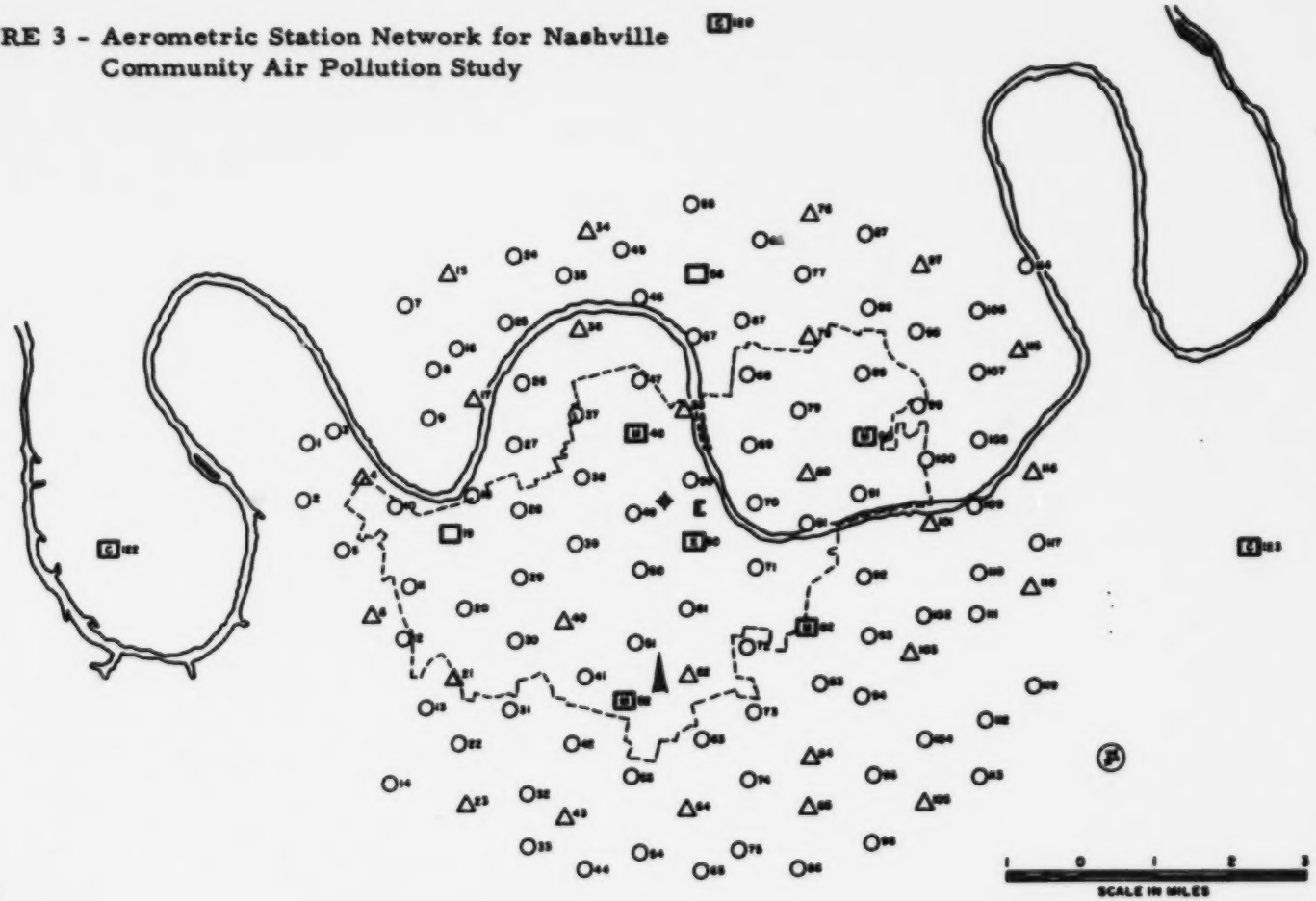

FIGURE 4 - Type 1 Aerometric Station

FIGURE 5 - Type II Aerometric Station

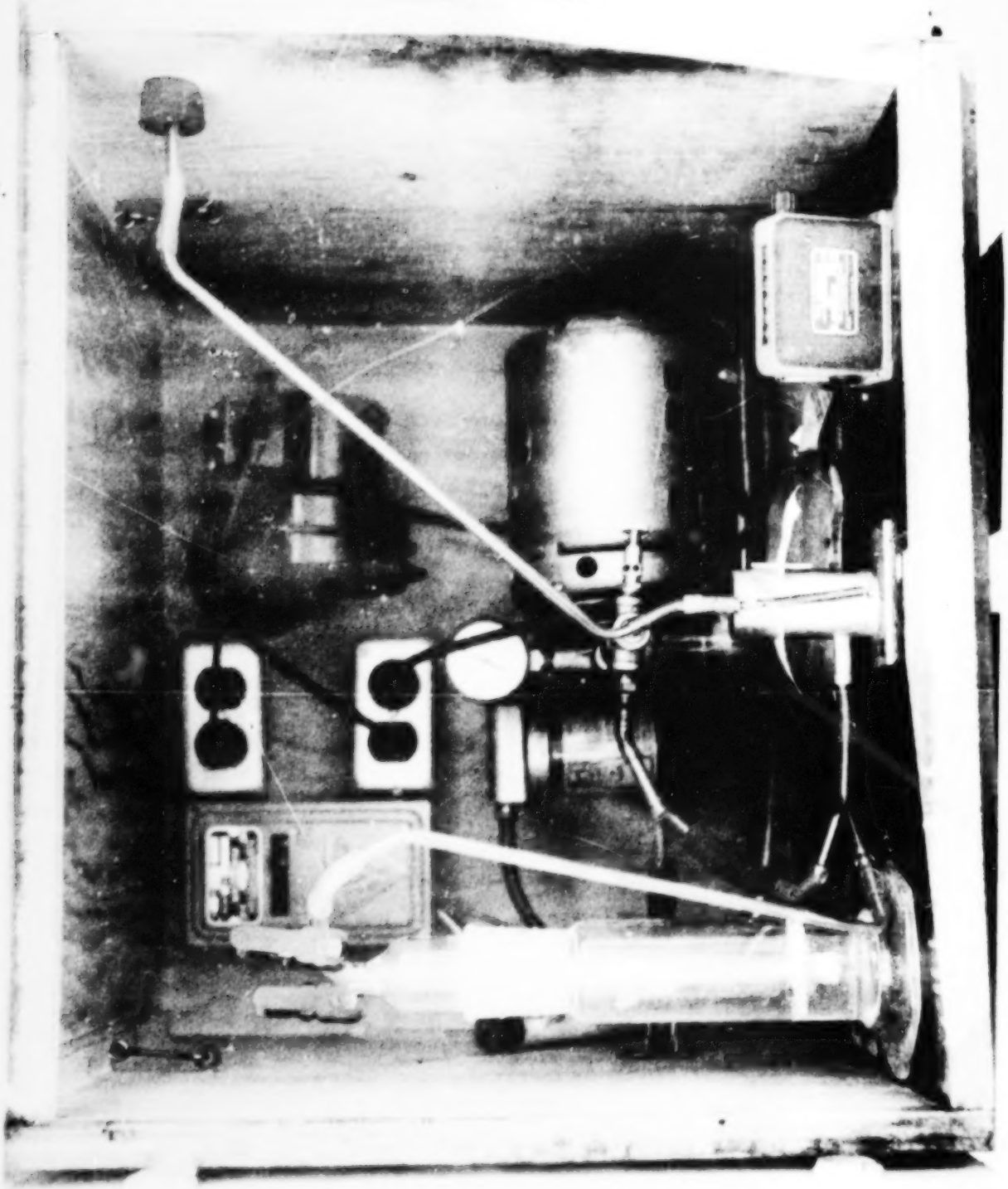

FIGURE 6 - Equipment in Type II Aerometric Station Shelter

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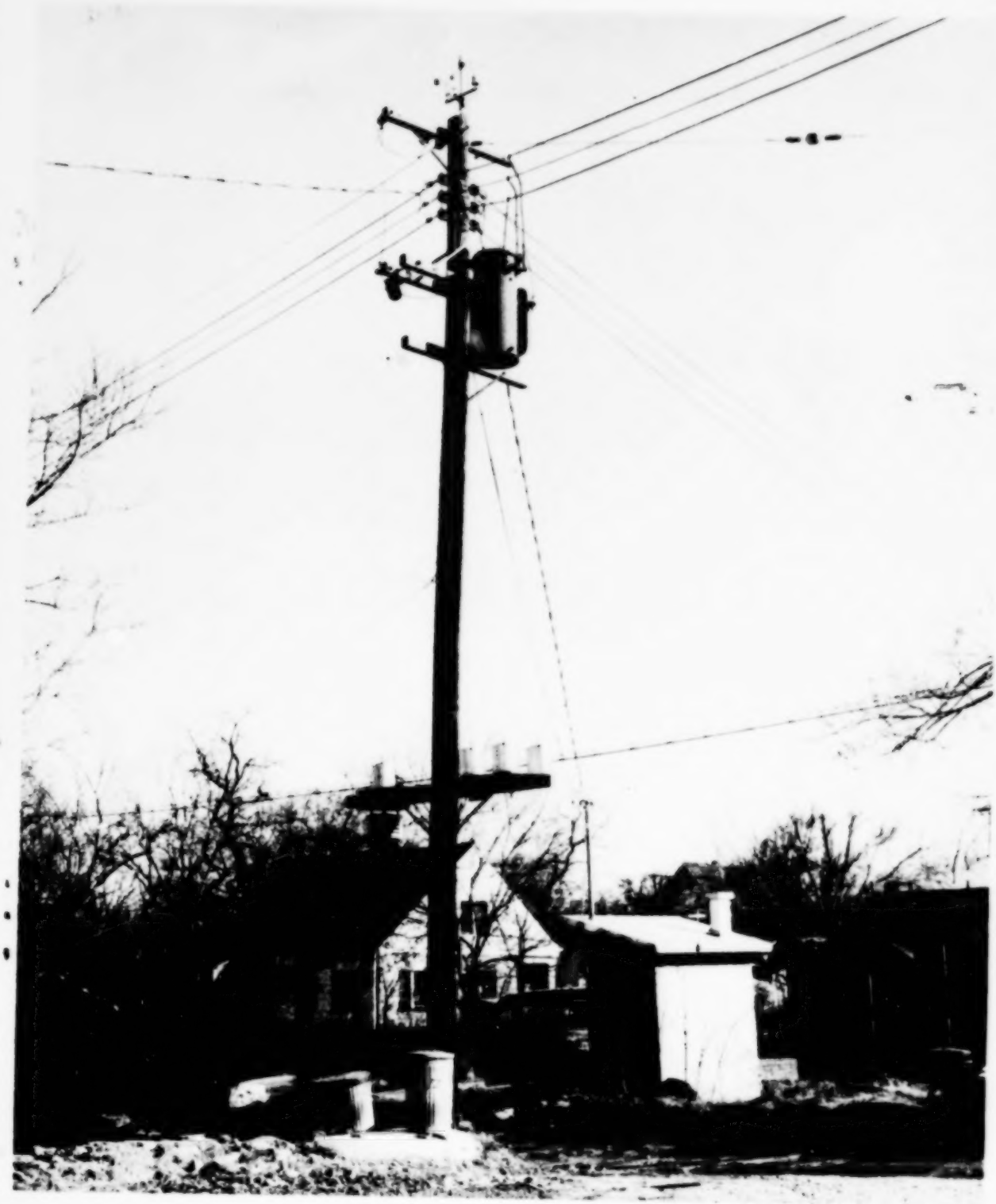

FIGURE 7 - Type III M Aerometric Station